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(Formerly NUREG-75/087)

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

9.2.5 ULTIMATE HEAT SINK

REVIEW RESPONSIBILITIES

Primary - ~~Auxiliary Systems Branch (ASB)~~Plant Systems Branch (SPLB)[1]

Secondary - None

I. AREAS OF REVIEW

The ultimate heat sink (UHS) is the source of cooling water provided to dissipate reactor decay heat and essential cooling system heat loads after a normal reactor shutdown or a shutdown following an accident, including a loss-of-coolant accident (LOCA).[2] The design of the UHS must satisfy the requirements of General Design Criteria 2, 5, 44, 45, and 46.

The ~~ASB~~SPLB[3] reviews the water sources which make up the ultimate heat sink. This includes the size, type of cooling water supply (e.g., ocean, lake, natural or manmade reservoir, river, or cooling tower), makeup sources to the ultimate heat sink, and the capability of the heat sink to deliver the required flow of cooling water at appropriate temperatures for normal, accident, or shutdown condition of the reactor. The UHS is reviewed to determine that design code requirements, as applicable to the assigned quality classifications and seismic categories, are met. A related area of review is the conveying system, which is generally the service water pumping system. The service water system is reviewed under Standard Review Plan (SRP)[4] Section 9.2.1.

1. The ultimate heat sink is reviewed with respect to the following considerations:

    a. The type of cooling water supply.

    b. The ability to dissipate the total essential station heat load.

USNRC STANDARD REVIEW PLAN

Standard review plans are prepared for the guidance of the Office of Nuclear Reactor Regulation staff responsible for the review of applications to construct and operate nuclear power plants. These documents are made available to the public as part of the Commission's policy to inform the nuclear industry and the general public of regulatory procedures and policies. Standard review plans are not substitutes for regulatory guides or the Commission's regulations and compliance with them is not required. The standard review plan sections are keyed to the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. Not all sections of the Standard Format have a corresponding review plan.

Published standard review plans will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D.C. 20555.

c. The effect of environmental conditions on the capability of the UHS to furnish the required quantities of cooling water, at appropriate temperatures and with any required chemical and purification treatment, for extended times after shutdown.

d. The effect of earthquakes, tornadoes, missiles, floods and hurricane winds on the availability of the source water. The UHS is also reviewed to ~~assure~~ ensure[5] that adverse environmental conditions including freezing will not preclude the safety function of the UHS.

e. Sharing of cooling water sources in multi-unit stations.

f. Applicable design requirements such as the high- and low-water levels of the source to determine their compatibility with the service water system.

2. ~~ASB~~SPLB[6] reviews the station heat input provided in the safety analysis report (SAR~~)~~[7] for the design of the UHS with respect to reactor system heat, sensible heat, and pump work, and station auxiliary system individual and total heat loads.

Portions of this review may be beyond the scope of the standard design certification application. The conceptual design and interface requirements will be reviewed for standard design certification. Detailed review will be performed for each site-specific application.[8]

<u>Review Interfaces</u>[9]

~~3.~~ ~~ASB~~SPLB[10] also performs the following reviews under the SRP sections indicated:

a. Review of flood protection is performed under SRP Section 3.4.1,

b. Review of the protection against internally generated missiles is performed under SRP Section 3.5.1.1,

c. Review of the structures, system, and components to be protected against externally generated missiles is performed under SRP Section 3.5.2, ~~and~~

d. Review of high- and moderate-energy pipe breaks is performed under SRP Section 3.6.1~~.~~,

e. Review of the program of surveillance and control techniques to detect and control the incidence of flow blockage problems due to aquatic bivalves and other fouling due to mud, silt, or corrosion products under SRP Section 9.2.1,[11] and

f. Coordination and review of fire protection is performed under SRP Section 9.5.1.[12]

In addition, ~~ASB~~SPLB[13] will coordinate other branch evaluations that interface with the overall review of the system as follows:

A.[14] The Reactor Systems Branch (~~RSB~~SRXB[15]) will confirm the heat loads transmitted to the UHS from the reactor coolant and emergency core cooling systems as part of its primary review responsibility for SRP Section 6.3.

B. The ~~Structural Engineering Branch (SEB)~~Civil Engineering and Geosciences Branch (ECGB)[16] will determine the acceptability of the design analyses, procedures, and criteria used to establish the ability of seismic Category I structures housing the system and supporting systems to withstand the effects of natural phenomena such as the safe shutdown earthquake (SSE), the probable maximum flood (PMF), and the tornado missiles as part of its primary review responsibility for SRP Sections 3.3.1, 3.3.2, 3.5.3, 3.7.1 through 3.7.4, 3.8.4, and 3.8.5. When the design of the UHS water source is formed by a dam or a system of dikes or levees, ECGB will also determine whether the design complies with "Federal Guidelines for Dam Safety."[17]

C. The ~~Materials Engineering Branch (MTEB)~~Materials and Chemical Engineering Branch (EMCB)[18] verifies the inservice inspection requirements are met for system components and the compatibility of the materials of construction with the service conditions as part of its primary review responsibility for SRP Section 6.1.1.

D. The ~~Instrumentation and Control Systems Branch (ICSB)~~Instrumentation and Controls Branch (HICB)[19] will verify the adequacy of the design, installation, inspection, and testing of all instrumentation and control systems required for proper operation as part of its primary review responsibility for SRP Section 7.1 and Appendix 7-A.

E. The ~~Power Systems Branch (PSB)~~Electrical Engineering Branch (EELB)[20] will verify the adequacy of the design, installation, inspection, and testing of all electrical systems required for proper operation as part of its primary review responsibility for SRP Section 8.3.1.

F. The ~~Hydrologic and Geotechnical Engineering Branch (HGEB)~~Civil Engineering and Geosciences Branch (ECGB)[21] verifies the ultimate heat sink water levels, meteorological and natural phenomena criteria (including ice effects),[22] and transient analysis of the cooling water inventory as part of its primary review responsibility for SRP Section 2.4.

~~The review for fire protection is coordinated and performed by the Chemical Engineering Branch as part of its primary review responsibility for SRP Section 9.5.1.~~[23]

G. The review for technical specifications is coordinated and performed by the ~~Licensing Guidance Branch~~Technical Specifications Branch (TSB)[24] as part of its primary review responsibility for SRP Section 16.0.

H. The review for quality assurance is coordinated and performed by the ~~Quality Assurance Branch~~Quality Assurance and Maintenance Branch (HQMB)[25] as part of its primary review responsibility for SRP Chapter 17.

~~In addition, ASB will coordinate other branch evaluations that interface with the overall review of the system as follows: The Reactor Systems Branch (RSB) will confirm the heat loads transmitted to the UHS from the reactor coolant and emergency core cooling systems as part of its primary review responsibility for SRP Section 6.3. The Structural Engineering Branch (SEB) will determine the acceptability of the design analyses, procedures, and criteria used to establish the ability of seismic Category I structures housing the system and supporting systems to withstand the effects of natural phenomena such as the safe shutdown earthquake (SSE), the probable maximum flood (PMF), and the tornado missiles as part of its primary review responsibility for SRP Sections 3.3.1, 3.3.2, 3.5.3, 3.7.1 through 3.7.4, 3.8.4, and 3.8.5. The Materials Engineering Branch (MTEB) verifies the inservice inspection requirements are met for system components and the compatibility of the materials of construction with the service conditions as part of its primary review responsibility for SRP Section 6.1.1. The Instrumentation and Control Systems Branch (ICSB) and Power Systems Branch (PSB) will verify the adequacy of the design, installation, inspection, and testing of all electrical systems (sensing, control, and power) required for proper operation as part of the primary review responsibilities for SRP Section 7.1 and Appendix 7-A for ICSB and SRP Section 8.3.1 for PSB. The Hydrologic and Geotechnical Engineering Branch (HGEB) verifies the ultimate heat sink water levels, meteorological and natural phenomena criteria, and transient analysis of the cooling water inventory as part of its primary review responsibility for SRP Section 2.4. The review for fire protection, technical specifications, and quality assurance are coordinated and performed by the Chemical Engineering Branch, Licensing Guidance Branch, and Quality Assurance Branch as part of their primary review responsibility for SRP Sections 9.5.1, 16.0, and 17.0, respectively.~~[26]

For those areas of review identified ~~above as being reviewed~~ as part of the primary ~~review~~ responsibility of other branches, the acceptance criteria and ~~their~~ methods of application are contained in the referenced SRP sections ~~corresponding to those branches~~.[27]

II. ACCEPTANCE CRITERIA

Acceptability of the design of the ultimate heat sink, as described in the applicant's ~~Safety Analysis Report (~~SAR~~)~~,[28] including related sections of Chapters 2 and 3 of the SAR, is based on specific general design criteria and regulatory guides and on independent calculations and staff judgments with respect to system adequacy.

The design of the ultimate heat sink is acceptable if the system and the associated complex of water sources, including retaining structures and canals or conduits connecting the sources with the station, are in accordance with the following criteria:

1. General Design Criterion 2 (GDC 2),[29] as related to structures housing the system and the system itself being capable of withstanding the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods. Acceptance is based on meeting the guidance of Regulatory Guide 1.29, Position C.1 and Regulatory Guide 1.27, Positions C.2 and C.3.

2. General Design Criterion 5 (GDC 5),[30] as related to shared systems and components important to safety being capable of performing required safety functions.

3. General Design Criterion 44 (GDC 44),[31] as related to:

   a. The capability to transfer heat loads from safety-related structures, systems, and components to the heat sink under both normal operating and accident conditions.

   b. Suitable component redundancy so that safety functions can be performed assuming a single active component failure coincident with loss of offsite power.

   c. The capability to isolate components, systems, or piping if required so that safety functions are not compromised.

   d. Acceptance is based upon meeting the guidance of Regulatory Guide 1.27, Positions C.2 and C.3; Regulatory Guide 1.72, Positions C.1, C.4, C.5, C.6, and C.7; as well as Branch Technical Position ASB 9-2.

4. General Design Criterion 45 (GDC 45),[32] as related to the design provisions to permit inservice inspection of safety-related components and equipment. For ultimate heat sink designs using dams, slopes, canals, or other water-control structures, acceptance for portions of the UHS is based on meeting the guidance of Regulatory Guide 1.127, "Inspection of Water-Control Structures Associated with Nuclear Power Plants."[33]

5. General Design Criterion 46 (GDC 46),[34] as related to the design provisions to permit operation functional testing of safety-related systems or components.

Technical Rationale

The technical rationale for application of these acceptance criteria to reviewing the ultimate heat sink is discussed in the following paragraphs:[35]

1. Compliance with GDC 2 requires that nuclear power plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as earthquake, tornado, hurricane, flood, tsunami, and seiche without loss of capability to perform their intended safety functions.

   GDC 2 is applicable to this SRP section because the reviewer considers the ultimate heat sink's capability to withstand natural phenomena. The ultimate heat sink must be able to provide an adequate supply of cooling water to cool the reactor and its essential support systems under all credible conditions. Regulatory Guides 1.27 and 1.29 describe methods acceptable to the staff for ensuring the capability of the ultimate heat sink to withstand the effects of natural phenomena, including earthquakes.

   Meeting the requirements of GDC 2 provides assurance that structures, systems, and components comprised by the plant's ultimate heat sink have been designed to withstand the most severe natural phenomena likely to occur.[36]

2. Compliance with GDC 5 requires that structures, systems, and components important to safety shall not be shared by nuclear power units unless it can be shown that such sharing will not impair their capability to perform intended safety functions.

   SRP Section 9.2.5 describes staff positions related to the design of the ultimate heat sink relative to the sharing of structures, systems, and components. GDC 5 applies to any multiple-unit facility in which a portion of the ultimate heat sink is shared by two or more units.

   Meeting the requirements of GDC 5 provides assurance that, in the event of an active or a passive failure at a multiple-unit site, the sharing of structures, systems, or components of the ultimate heat sink will not affect the safe shutdown of any unit.[37]

3. Compliance with GDC 44 requires that a system be provided to transfer heat from structures, systems, and components important to safety to an ultimate heat sink. The system must be able to function under normal and accident conditions, assuming a single failure.

   GDC 44 applies to this SRP section because the reviewer evaluates the design of the ultimate heat sink, including assumptions concerning heat loads, redundancy of components, capability to isolate components, and single failures. Regulatory Guides 1.27 and 1.72 describe guidance acceptable to the staff regarding the design of the ultimate heat sink and of fiberglass piping for spray pond applications. In addition, Branch Technical Position ASB 9-2 describes methods acceptable to the staff for calculating residual decay energy.

   Meeting the requirements of GDC 44 provides assurance that the ultimate heat sink will function as designed to transfer heat from structures, systems, and components as required under normal and accident conditions, assuming a single failure.[38]

4. Compliance with GDC 45 requires that the cooling water system be designed to permit appropriate periodic inspection of important components (e.g., heat exchangers and piping) to ensure the integrity and capability of the system.

   SRP Section 9.2.5 describes staff positions related to the design of the ultimate heat sink, including inspection of safety-related components and equipment. Regulatory Guide 1.127 describes methods acceptable to the staff for the inspection of ultimate heat sink designs using dams, slopes, canals, or other water-control structures.

   Meeting the requirements of GDC 45 provides assurance that components and equipment of the ultimate heat sink can and will be inspected, thereby ensuring that the system will perform its intended safety function.[39]

5. Compliance with GDC 46 requires that the cooling water system be designed to permit appropriate periodic pressure and functional testing to ensure the leaktight integrity and operability of its components, as well as the operability of the system as a whole, under conditions as close to the design basis as practical.

SRP Section 9.2.5 describes staff positions related to the design of the ultimate heat sink, including testing of the system and its components.

Meeting the requirements of GDC 46 provides assurance that components and equipment of the ultimate heat sink can and will be tested, thereby ensuring that the system will perform its intended safety function.[40]

III. REVIEW PROCEDURES

The procedures below are used during the construction permit (CP) review to determine that the design criteria and bases and the preliminary design as set forth in the preliminary safety analysis report meet the acceptance criteria given in subsection II of this SRP section. For operating license (OL) reviews, the procedures are used to verify that the initial design criteria and bases have been appropriately implemented in the final design as set forth in the final safety analysis report.

Upon request from the primary reviewer, the coordinated review branches will provide input for the areas of review stated in subsection I of this SRP section. The primary reviewer obtains and uses such input as required to ~~assure~~ ensure that this review procedure is complete.

Availability of an adequate supply of water for the ultimate heat sink is a basic requirement for any nuclear power plant. There are various methods of satisfying the requirement, e.g., a large body of water such as an ocean, lake, or natural or manmade reservoir, a river, or cooling ponds or towers, or combinations thereof. The design of the ultimate heat sink tends to be unique for each nuclear plant, depending upon its particular geographical location. For the purpose of this SRP section, typical procedures are established for use in identifying the essential features of an ultimate heat sink. For installations where these general procedures are not completely adequate, the reviewer supplements them as necessary.

1. The SAR is reviewed for the overall arrangement and type of ultimate heat sink proposed. The reviewer verifies that the UHS is designed so that system function is maintained as required when subjected to adverse environmental phenomena including freezing and to a loss of offsite power. The reviewer evaluates the system to determine that:

    a. The heat inputs that are used in the design of the UHS are conservative. The reviewer makes an independent evaluation of the applicant's calculated heat loads. The UHS heat loads include heat due to decay of radioactive material, sensible heat, pump work, and the heat load from the operation of the station auxiliary systems serving and dependent upon the UHS.

    b. Operational data from plants of similar design confirm, where possible, the heat input values given for sensible heat, pump work, and station auxiliary systems.

2. The reviewer verifies that:

a. The total essential station heat load and system flow requirements of the service water system are compatible with the heat rejection capability of the UHS.

b. The UHS has the capability to dissipate the maximum possible total heat load, including LOCA under the worst combination of adverse environmental conditions including freezing, and has provisions for cooling the unit (or units, including LOCA for one unit for a multi-unit station with one heat sink) for a minimum of 30 days without makeup unless acceptable makeup capabilities can be demonstrated. This capability is verified by independent check calculations.

c. The connecting channels, structures, manmade embankments and dams, and conduits to and from the UHS are capable of withstanding design basis natural phenomena in combination with other site-related events and that a single failure of any manmade feature resulting from such phenomena or events cannot prevent adequate cooling water flow or adversely effect the temperature of the water from the sink.

d. The design of any dams, slopes, canals, or other water-control structures associated with the ultimate heat sink have provisions for inservice inspection and surveillance.[41]

e. The design provides for surveillance and control techniques to detect and control the incidence of flow blockage problems due to aquatic bivalves and other fouling due to mud, silt, or corrosion products, as recommended in Generic Letter 89-13 (Reference 12). The program for surveillance and control is reviewed by SPLB as indicated in subsection I of this SRP section.[42]

3. Plants utilizing cooling towers as the ultimate heat sink are reviewed as described above and in addition the reviewer determines that:

a. The tower structure and basin design bases in the SAR include requirements for withstanding design basis natural phenomena or combinations of such phenomena at historically observed intensities. The natural phenomena to be considered include tornadoes, tornado missiles, hurricane winds, floods, and the SSE.

b. The results of failure modes and effects analyses show that the mechanical systems (fans, pumps, and controls) can withstand a single active failure in any of these systems, including failure of any auxiliary electric power source, and not prevent delivery of water in the quantities and at temperatures required for safe shutdown.

c. Adequate net positive suction head (NPSH) can be provided to all essential pumps considering variations of water level in the basins. This is verified by performing independent calculations.

d. The towers can provide the design cooling water temperature under the worst combination of adverse environmental conditions including freezing, and that the supply of water in the basins can provide a 30-day capability for long-term cooling at the required temperature without makeup unless acceptable makeup capabilities can be demonstrated. This is verified by independent calculations.

e. Cooling towers or spray ponds used as a UHS and designed to withstand the effects of tornado missiles need not be designed to seismic Category I if another UHS is also available that is designed to meet the seismic classification guidelines of Regulatory Guide 1.27.

4. Reactor sites that utilize large natural or manmade water sources which for all practical purposes have an infinite supply of water are reviewed as described in items 1 and 2 above, and in addition the reviewer determines:

a. By evaluation of the SAR information or independent calculations that the water source is adequate taking into account the effects of design basis natural phenomena such as tornadoes, hurricane winds, probable maximum floods, tsunamis, seiches, and the SSE.

b. By reviewing the SAR preliminary site and plant arrangement sketches (CP) and site drawings and plant arrangement drawings (OL) that the design of the intake and outlet conduits (open or closed type) are properly separated to prevent recirculation or water temperature stratification.

c. That manmade earth dam, dike, or other structure design bases in the SAR include requirements for withstanding the design basis natural phenomena or combinations of such phenomena at historically observed intensities. In the event of failure of a dam, dike, or other structure not designed to withstand the design basis natural phenomena (particularly the SSE), sufficient water must remain in the source pool to ~~assure~~ ensure a cooling water supply for a minimum of 30 days, with adequate cooling capability so that the required cooling water temperature to the service water system inlet is not exceeded.

5. As indicated in subsection I of this SRP section, the review of seismic design is performed by ~~SEB~~ECGB[43] and the review for seismic and quality group classification is performed by ~~MEB~~EMEB.[44]

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.[45]

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided and the review supports conclusions of the following type, to be included in the staff's safety evaluation report (SER):[46]

> The ultimate heat sink review included the size, type of cooling supply (e.g., large body of water, ocean, lake, natural or manmade reservoir, river, pond, or cooling tower), and makeup sources to the ultimate heat sink. The review has determined the adequacy of the applicant's proposed design criteria, design bases and safety classification for the ultimate heat sink and the requirements for delivering cooling water for a safe shutdown during normal and accident conditions. The UHS and its supporting systems meet seismic Category I, Quality Group C requirements. The staff concludes that the design of the ultimate heat sink is acceptable and meets the requirements of General Design Criteria 2, 5, 44, 45, and 46. This conclusion is based on the following:

1. The applicant has met the requirements of General Design Criterion 2 with respect to being capable of withstanding the effects of ~~earthquakes~~natural phenomena such as earthquakes, tornadoes, tornado missiles, hurricanes, and floods.[47] Acceptance is based on meeting the guidance of Regulatory Guide 1.29, Position C.1, and Regulatory Guide 1.27, Positions C.2 and C.3.[48] In addition, for a UHS formed by a dam or a system of dikes or levees, acceptance is also based on the UHS being designed in accordance with "Federal Guidelines for Dam Safety," as applicable.[49]

2. The applicant has met the requirements of General Design Criterion 5 with respect to sharing of structures, systems, and components by demonstrating that such sharing does not affect the safe shutdown of either unit in the event of an active or passive failure.

3. The applicant has met the requirements of General Design Criterion 44 with respect to the ultimate heat sink. Acceptance is based on meeting the guidance of Regulatory Guides 1.27, positions C.2 and C.3;[50] Regulatory Guide 1.72, positions C.1, C.4, C.5, C.6, and C.7;[51] as well as Branch Technical Position ASB 9-2.

4. The applicant has met the requirements of General Design Criterion 45 with respect to inservice inspection of the safety-related components and equipment by demonstrating the accessibility of the UHS system for periodic inspections. For dams, slopes, canals, or other water-control structures, acceptance is based on meeting the guidance of Regulatory Guide 1.127.[52]

5. The applicant has met the requirements of General Design Criterion 46 with respect to periodic pressure and functional testing to ~~assure~~ ensure structural and leaktight integrity, operability, and performance of its active components, and operability of the system as a whole by demonstrating the capability to operate the system at full capacity during normal startup or shutdown procedures or during normal operation without degrading the system to provide for a safe shutdown or to mitigate the consequences of an accident.

For design certification reviews, the findings will also summarize, to the extent that the review is not discussed in other safety evaluation report sections, the staff's evaluation of inspections, tests, analyses, and acceptance criteria (ITAAC), including design acceptance criteria (DAC), site interface requirements, and combined license action items that are relevant to this SRP section.[53]

V. IMPLEMENTATION

The following is intended to provide guidance to the applicants and licensees regarding the NRC staff's plans for using this SRP section.

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.[54] Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.[55]

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

2. 10 CFR Part 50, Appendix A, General Design Criterion 5, "Sharing of Structures, Systems, and Components."

3. 10 CFR Part 50, Appendix A, General Design Criterion 44, "Cooling Water."

4. 10 CFR Part 50, Appendix A, General Design Criterion 45, "Inspection of Cooling Water System."

5. 10 CFR Part 50, Appendix A, General Design Criterion 46, "Testing of Cooling Water System."

6. Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants."

7. Regulatory Guide 1.29, "Seismic Design Classification."

8. Regulatory Guide 1.72, "Spray Pond ~~Plastic~~ Piping made from Fiberglass-Reinforced Thermosetting Resin."[56]

9. Branch Technical Position ASB 9-2, "Residual Decay Energy for Light Water Reactors for Long-Term Cooling."

10. Regulatory Guide 1.127, "Inspection of Water-Control Structures Associated with Nuclear Power Plants."[57]

11. Federal Coordinating Council for Science, Engineering, and Technology, "Federal Guidelines for Dam Safety," June 25, 1979.[58]

12. NRC Letter to All Holders of Operating Licenses or Construction Permits for Nuclear Power Plants, "Service Water System Problems Affecting Safety-Related Equipment, (Generic Letter 89-13)" July 18, 1989.[59]

13. ANS 5.1, "Decay Heat Power for Light Water Reactors," October 1979.[60]

BRANCH TECHNICAL POSITION ASB 9-2

RESIDUAL DECAY ENERGY FOR LIGHT-WATER REACTORS FOR LONG-TERM COOLING

A. BACKGROUND

The Auxiliary Systems Branch has developed acceptable assumptions and formulations that may be used to calculate the residual decay energy release rate for light-water-cooled reactors for long-term cooling of the reactor facility.

Experimental data (Refs. 1 and 2) on total beta and gamma energy releases for long half-life (> 60 seconds) fission products from thermal neutron fission of U-235 have been considered reliable for decay times of 10^3 to 10^7 seconds. Over this decay time, even with the exclusion of short-lived fission products, the decay heat rate can be predicted to within 10% of experimental data (Refs. 3, 7, and 8).

The short-lived fission products contribute appreciably to the decay energy for decay times less than 10^3 seconds. Although consistent experimental data are not as numerous (Refs. 4 and 5) and the results of various calculations differ, the effect of all uncertainties can be treated in the zero to 10^3 second time range by a suitably conservative multiplying factor.

B. BRANCH TECHNICAL POSITION[161]

1. Fission Product Decay

For finite reactor operating time (t_o) the fraction of operating power,

$P/Po(t_o, t_s)$, to be used for the fission product decay power at a time

t_s after shutdown may be calculated as follows:

$$\frac{P}{P_o}(\infty, t_s) = \frac{1}{200} \sum_{n=1}^{n=11} A_n e^{-a_n t_s} \qquad \mathbf{(1)}$$

[1] ANS 5.1, "Decay Heat Power for Light Water Reactors" (October 1979), can also be used to establish decay heat generation rates in lieu of the methods described below.

$$\frac{P}{P_o}(t_o, t_s) = (1+K)\frac{P}{P_o}(\infty, t_s) - \frac{P}{P_o}(\infty, t_o + t_s) \qquad \textbf{(2)}$$

where:

P/P_o = fraction of operating power

t_o = cumulative reactor operating time, seconds

t_s = time after shutdown, seconds

K = uncertainty factor; 0.2 for $0 \le t_s < 10^3$ and 0.1 for $10^3 \le t_s \le 10^7$

A_n, a_n = fit coefficients having the following values:

n	A_n	a_n (sec^{-1})
1	0.5980	1.772×10^{0}
2	1.6500	5.774×10^{-1}
3	3.1000	6.743×10^{-2}
4	3.8700	6.214×10^{-3}
5	2.3300	4.739×10^{-4}
6	1.2900	4.810×10^{-5}
7	0.4620	5.344×10^{-6}
8	0.3280	5.716×10^{-7}
9	0.1700	1.036×10^{-7}
10	0.0865	2.959×10^{-8}
11	0.1140	7.585×10^{-10}

The expressions for finite reactor operation may be used to calculate the decay energy from a complex operating history; however, in accident analysis a suitably conservative history should be used. For example, end-of-first-cycle calculations should assume continuous operation at full power for a full-cycle time period, and end-of-equilibrium-cycle calculations should assume appropriate fractions of the core to have operated continuously for multiple-cycle times.

An operating history of 16,000 hours is considered to be representative of many end-of-first or equilibrium cycle conditions and is, therefore, acceptable. In calculating the fission produce decay energy, a 20% uncertainty factor (K) should be added for any cooling time less than 10^3 seconds, and a factor of 10% should be added for cooling times greater than 10^3 but less than 10^7 seconds.

2. <u>Heavy Element Decay Heat</u>

The decay heat generation due to the heavy elements U-239 and Np-239 may be calculated according to the following expressions (Ref. 6):

$$\frac{P(U{-}239)}{P_o} = 2.28x10^{-3}C\frac{\sigma_{25}}{\sigma_{f25}}[1-e^{4.91x10^{-4}t_o}][e^{4.91x10^{-4}t_s}] \tag{3}$$

$$\frac{P(U{-}239)}{P_o} = 2.17x10^{-3}C\frac{\sigma_{25}}{\sigma_{f25}}[1.007(1-e^{3.41x10^{-6}t_o})(e^{3.41x10^{-6}t_s}) - 0.007(1-e^{4.91x10^{-4}t_o})(e^{4.91x10^{-4}t_s})] \tag{4}$$

62

where:

P (U-239)/Po = fraction of operating power due to U-239

P (Np-239)/Po = fraction of operating power due to Np-239

t_o = cumulative reactor operating time, seconds

t_s = time after shutdown, seconds

C = conversion ratio, atoms of Pu-239 produced per atom of U-235 consumed

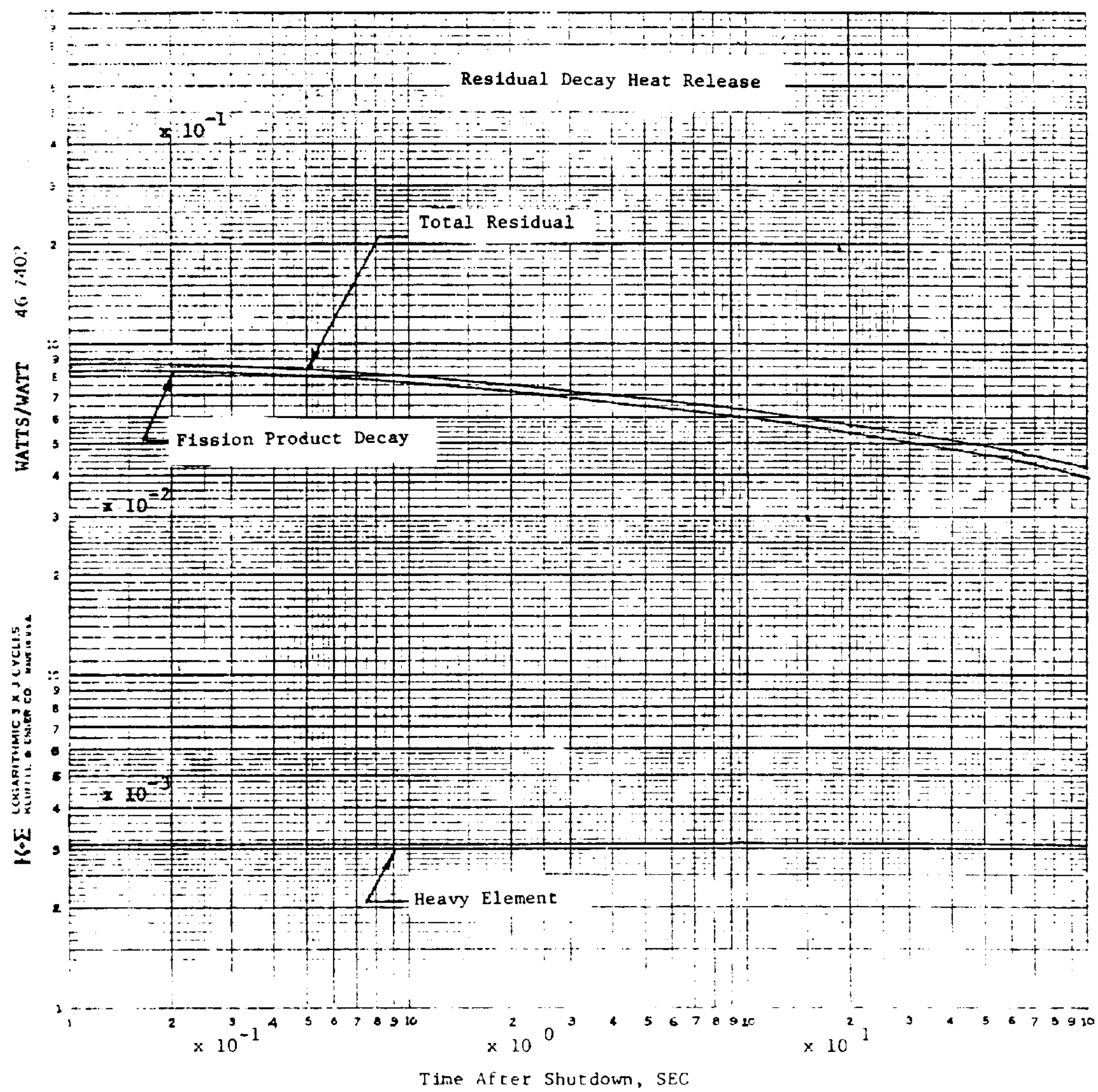
σ_{25}= effective neutron absorption cross section of U-235

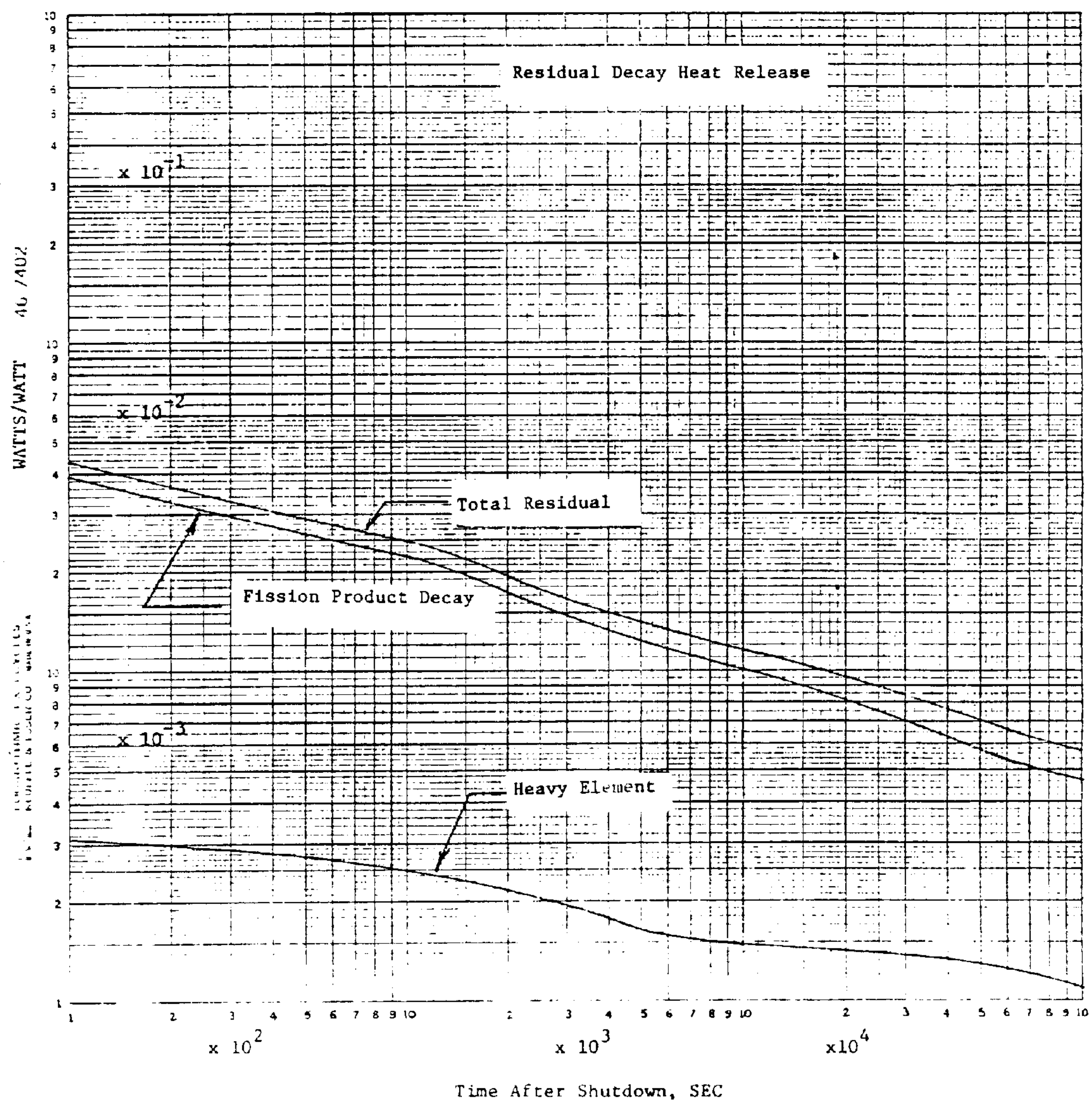
σ_{f25} = effective neutron fission cross section of U-235

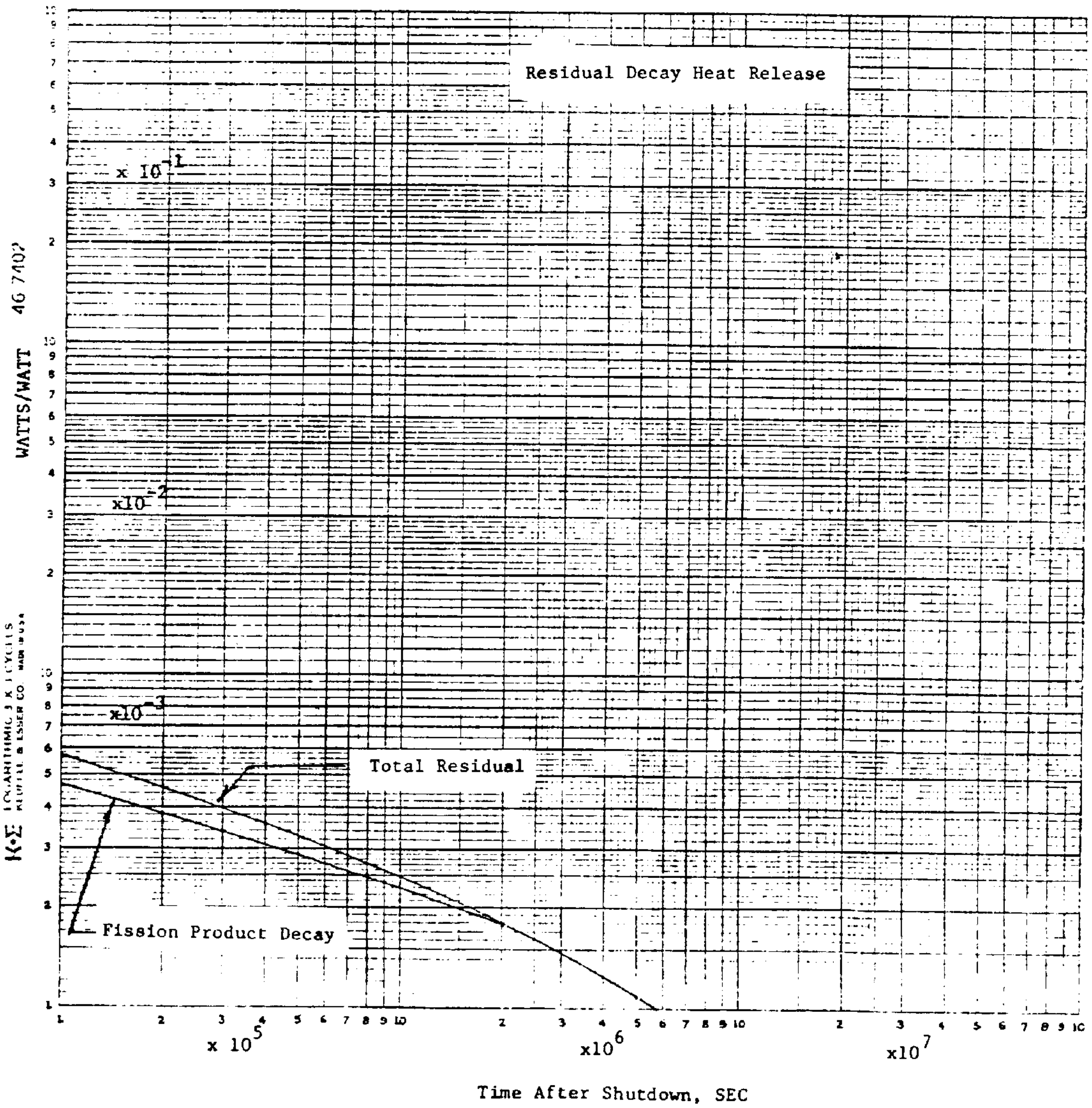
The product of the terms $C \cdot \sigma_{25}/\sigma_{f25}$ can be conservatively specified as 0.7.

The nuclear parameters for energy production by the heavy elements U-239 and Np-239 are relatively well known. Therefore, the heavy element decay heat can be calculated with a conservatively estimated product term of $C \cdot \sigma_{25}/\sigma_{f25}$ without applying any other uncertainty correction factor.

3. Figures 1, 2, and 3[63] give the residual decay heat release in terms of fractions of full reactor operating power based on a reasonably realistic reactor operating time of 16,000 hours.


Residual Decay Heat Release
x 10^-1
Total Residual
Fission Product Decay
x 10^-2
x 10^-3
Heavy Element
WATTS/WATT
x 10^-1
x 10^0
x 10^1
Time After Shutdown, SEC


Residual Decay Heat Release
x 10^-1
x 10^-2
x 10^-3
WATTS/WATT
Total Residual
Fission Product Decay
Heavy Element
x 10^2
x 10^3
x10^4
Time After Shutdown, SEC


Residual Decay Heat Release
x 10^-1
x10^-2
x10^-3
Total Residual
Fission Product Decay
WATTS/WATT
x 10^5
x10^6
x10^7
Time After Shutdown, SEC

C. REFERENCES

1. J. F. Perkins and R. W. King, "Energy Release From the Decay of Fission Products, Nuclear Science and Engineering," Vol. 3, 726 (1958).

2. A. M. Perry, F. C. Maienschein, and D. R. Vondy, "Fission-Product Afterheat: A Review of Experiments Pertinent to the Thermal-Neutron Fission of ^{235}U," ORNL-TM-4197, Oak Ridge National Laboratory, October 1973.

3. A. Tobias, "The Energy Release From Fission Products," Journal of Nuclear Energy, Vol. 27, 725 (1973).

4. J. Scobie, R. D. Scott, and H. W. Wilson, "Beta Energy Release Following the Thermal Neutron Induced Fission of U and ^{235}U," Journal of Nuclear Energy, Vol. 25, 1 (1971).

5. L. Costa and R. de Tourreil, "Activite β et α Des Products d'une Fission de ^{235}U et ^{239}Pu," Journal of Nuclear Energy, Vol. 25, 285 (1971).

6. Proposed ANS Standard, "Decay Energy Release Rates Following Shutdown of Uranium-Fueled Thermal Reactors," American Nuclear Society, October 1973.

7. J. Scobie and R. D. Scott, "Calculation of Beta Energy Release Rates Following Thermal Neutron Induced Fission of ^{233}U, ^{235}U, ^{239}Pu, and ^{241}Pu," Journal of Nuclear Energy, Vol. 25, 339 (1971).

8. K. Shure, "Fission Product Decay Energy," WAPD-BT-24, Westinghouse Electric Corporation, December 1961.

9. ANS 5.1, "Decay Heat Power for Light Water Reactors," October 1979.[64]

SRP Draft Section 9.2.5

Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Current primary review branch name and abbreviation	Changed PRB to Plant Systems Branch (SPLB).
2.	Editorial	Defined LOCA.
3.	Current primary review branch abbreviation	Changed PRB to SPLB.
4.	Editorial	Defined SRP.
5.	Editorial	Changed "assure" to "ensure" (global change for this SRP section).
6.	Current primary review branch abbreviation	Changed PRB to SPLB.
7.	Editorial	Defined SAR.
8.	SRP-UDP format item	Added guidance to AREAS OF REVIEW on scope of the design certification review.
9.	SRP-UDP format item	Added "Review Interfaces" under AREAS OF REVIEW.
10.	Current primary review branch abbreviation	Changed PRB to SPLB.
11.	**Integrated Impact 420**	Added a review interface to SRP 9.2.1 for review of the program for surveillance and control techniques to prevent fouling of service water systems in accordance with GL 89-13.
12.	Current primary review branch responsibility	Responsibility for this area of review reassigned from Chemical Engineering Branch to Plant Systems Branch (see item 23 below).
13.	Current primary review branch abbreviation	Changed PRB to SPLB.
14.	SRP-UDP format item	Divided the existing paragraph into lettered subsections, one for each review branch interface. The existing text and order was preserved, except for branch abbreviations, which were changed to agree with the reorganization.
15.	Current review branch abbreviation	Changed review branch to Reactor Systems Branch (SRXB).
16.	Current review branch name and abbreviation	Changed review branch to Civil Engineering and Geosciences Branch (ECGB).

Item	Source	Description
17.	Integrated Impact No. 423	Added a sentence to indicate that ECGB will review the design for compliance with the "Federal Guidelines for Dam Safety," as applicable, for designs involving dams or a system of dikes or levees.
18.	Current review branch name and abbreviation	Changed review branch to Materials and Chemical Engineering Branch (EMCB).
19.	Current review branch name and abbreviation	Changed review branch to Instrumentation and Controls Branch (HICB).
20.	Current review branch name and abbreviation	Changed review branch to Electrical Engineering Branch (EELB).
21.	Current review branch abbreviation	Changed review branch to Civil Engineering and Geosciences Branch (ECGB).
22.	Editorial	Added "(including ice effects)" to ECGB review interface responsibilities as part of its primary review responsibility for SRP Section 2.4.7.
23.	Current review branch abbreviation	Responsibility for fire protection reassigned to SPLB (see item 10 above).
24.	Current review branch name and abbreviation	Changed review branch to Technical Specifications Branch (TSB).
25.	Current review branch name and abbreviation	Changed review branch to Quality Assurance and Maintenance Branch (HQMB).
26.	SRP-UDP format item	This is the review interface paragraph that has been deleted and replaced by the numbered paragraphs above.
27.	Editorial	simplified for clarity and readability
28.	Editorial	Used SAR as defined in item 8 above.
29.	Editorial	Introduced "GDC 2" as initialism for "General Design Criterion 2."
30.	Editorial	Introduced "GDC 5" as initialism for "General Design Criterion 5."
31.	Editorial	Introduced "GDC 44" as initialism for "General Design Criterion 44."
32.	Editorial	Introduced "GDC 45" as initialism for "General Design Criterion 45."
33.	Integrated Impact No. 423	Added a sentence to indicate that inservice inspection for dams, slopes, canals, or other water-control structures is based on meeting the guidance of Regulatory Guide 1.127.
34.	Editorial	Introduced "GDC 46" as initialism for "General Design Criterion 46."

Item	Source	Description
35.	SRP-UDP format item	Added "Technical Rationale" and lead-in paragraph to ACCEPTANCE CRITERIA.
36.	SRP-UDP format item	Added technical rationale for GDC 2.
37.	SRP-UDP format item	Added technical rationale for GDC 5.
38.	SRP-UDP format item	Added technical rationale for GDC 44.
39.	SRP-UDP format item	Added technical rationale for GDC 45.
40.	SRP-UDP format item	Added technical rationale for GDC 46.
41.	Integrated Impact No. 423	Added a sentence indicating that the reviewer should verify the design of any dam, slope, canal, or other water-control structures have provisions for inservice inspection and surveillance.
42.	Integrated Impact No. 420	Added a statement under REVIEW PROCEDURES regarding the review of design provisions for the detection and control of flow blockage problems due to biological and other fouling.
43.	Current review branch abbreviation	Changed review branch to ECGB.
44.	Current review branch abbreviation	Changed review branch to EMEB.
45.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
46.	Editorial	Provided "SER" as initialism for "safety evaluation report."
47.	Editorial	Modified for consistency with paragraph II.1.
48.	Editorial	Modified for consistency with paragraph II.1.
49.	Integrated Impact No. 423	Added a sentence to indicate that acceptance is based on the applicant's commitment to design the UHS in accordance with the "Federal Guidelines for Dam Safety," where applicable, when the UHS is formed by a dam or a system of dikes or levees.
50.	Editorial	Modified for consistency with paragraph II.3.
51.	Editorial	Modified for consistency with paragraph II.3.
52.	Integrated Impact No. 423	Added a sentence to indicate that inservice inspection for dams, slopes, canals, or other water-control structures is based on meeting the guidance of Regulatory Guide 1.127.

SRP Draft Section 9.2.5
Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
53.	SRP-UDP Format Item, Implement 10 CFR 52 Related Changes	To address design certification reviews a new paragraph was added to the end of the Evaluation Findings. This paragraph addresses design certification specific items including ITAAC, DAC, site interface requirements, and combined license action items.
54.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50.
55.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
56.	Editorial	Corrected the title of the Regulatory Guide.
57.	Integrated Impact No. 423	Added Regulatory Guide 1.127 to the list of references.
58.	Integrated Impact No. 423	Added "Federal Guidelines for Dam Safety" to the list of references.
59.	Integrated Impact No. 420	Added Generic Letter 89-13 to the list of references.
60.	Integrated Impact No. 421	Added ANS 5.1 to the list of references as Reference 13.
61.	Integrated Impact No. 421	Added footnote 1 to BTP ASB 9-2 to indicate acceptability of using ANS 5.1 (October 1979).
62.	Editorial	Retyped equations. Corrected a typographical mistake in equation (2), i.e, added a comma before to in the last parenthetical term.
63.	SRP-UDP format item	In-text callouts are provided for Figures 1, 2, and 3. None of the three figures are labeled, however, and all three should be revised to maximize the benefit they provide to reviewers.
64.	Integrated Impact No. 421	Added ANS 5.1 to the list of references as Reference 9.

SRP Draft Section 9.2.5

Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
420	Add review procedures to include a reference to Generic Letter 89-13 regarding detection and control of aquatic bivalves and debris in the ultimate heat sink.	III.2.e and VI.12
421	Revise Branch Technical Position (BTP) ASB 9-2 to allow the use of ANS 5.1 (October 1979) for decay heat calculations in lieu of the method set out in the BTP.	VI, Reference 13; BTP ASB 9-2 (SRP 9.2.5); Section C to BTP ASB 9-2 (Reference 9)
422	Update Regulatory Guide 1.27 to delete reference to the Operating Basis Earthquake.	No changes were made to SRP Section 9.2.5 based on Integrated Impact No. 422.
423	Add a reference to Regulatory Guide 1.127 and "Federal Guidelines for Dam Safety."	I.B; II.4; III.2.d; IV.1; IV.4; VI.10; and VI.11
729	RG 1.72 is cited in this SRP Section. ASTM D1599 1974 is endorsed by RG 1.72. The latest version of this standard is ASTM D1599 1988. Consider revising the RG to cite the latest standard.	This impact will not be processed further. Action will be tracked by IPD-7.0 Form 9.2.5-2.